

APPENDIX E:
WOOD-WASTE-FIRED BOILER EMISSIONS TEST SUMMARIES

**Emission Test Report
for
The University of Idaho
Wood Fired Boiler
of
Particulate Matter
Carbon Monoxide
&
Opacity**

TE&E Project #9639

March 23, 1998

**Prepared for:
The University of Idaho
Facilities Management
Moscow, ID 83844-1231
(208) 885-6246**

**Prepared by:
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1. INTRODUCTION

1.1 Summary of Test Program

The University of Idaho (U of I) contracted with Travis Energy & Environment, Inc. (TE&E) to perform emissions testing of the Solid Fuels Inc. furnace at their Moscow power plant. The boiler was fired by hogged fuel and wood chips.

The specific test objectives were to measure particulate matter and carbon monoxide emissions, and opacity from the boiler. Carbon monoxide testing was carried out on February 26, 1998, the opacity determination was done on February 27, 1998, and the particulate testing was done on February 28, 1998.

1.2 Key Personnel

The key personnel who coordinated the test program were:

Project Manager	Brent N. Travis, TE&E	208-772-9149
University Contact	Don Husky, U of I	208-885-7350
Plant Contact	Gerald Hanks, U of I	208-885-6271

2. PLANT AND SMAPLING LOCATION DESCRIPTION

2.1 Process Description and Operation

The Solid Fuels Inc. furnace fires a Nebraska boiler. A block diagram of the facility is shown in **Figure 1**. The Nebraska boiler's nameplate ring is 60,000 pph of steam. Operating steam flows during testing ranged between 48,000 and 81,000 pph of 127 to 160 psig steam. A steam production factor of 6.90 lbs of steam per bone dry lb of wood was determined as shown in Appendix A. The properties of the wood waste fired are presented in **Table 2-1**. Methods of analysis and number of samples tested are stated in Appendix A. **Table 2-2** shows fuel and steam average flow rates for each test calculated from the steam integrator and the above steam production factor.

Chart trends showing steam flow, steam pressure, % oxygen, % opacity, collector pressure and system temperature profiles are presented in Appendix A.

Table 2-1 Fuel Properties

Property	Average	Maximum	Minimum	Standard Deviation
Moisture, wt%	51.2	57.3	32.8	3.55
Combustibles, wt%, dry basis	98.4	98.9	98.1	0.25
Ash, dry wt%	1.64	1.95	1.12	0.25
Higher Heating Value BTU / dry lb	9498	11074	8644	488

Table 2-2 Process Flow Rates

Test	Fuel BD lbs	Fuel Flow BD lbs/hr	Steam 1,000 lbs	Steam Flow kpph
1	12174	11781	84	81
2	9130	8695	63	60
3	12609	7642	87	53
5	N/A	N/A	N/A	N/A
6	12319	8213	85	57
7	10145	7515	70	52
8	9420	6978	65	48

2.2 Control Equipment Description

Emissions from the boiler are controlled by an internal cyclone. Opacity is recorded by a continuous emissions monitoring system (CEMS). Both the boiler and CEMS were in sound working condition.

2.3 Flue Gas Sampling Locations

The unit has an inner stack diameter of 59". Two sampling ports (90 degree offset) are located greater than eight stack diameters, from the top of the stack which is the nearest downstream flow disturbance. The upstream distance to the nearest flow disturbance is approximately 4.2 stack diameters from the ports. Twenty-four traverse points were sampled for the Solid Fuels Stoker unit particulate test; stack traverse points were located at:

1.24, 3.95, 6.96, 10.44, 14.75, 21.00, 38.00, 44.25, 48.56, 52.04, 55.05, and 57.76 inches along the two diameters tested.

2.4 Process Sampling Locations

Fuel samples were collected from the boiler feed system during testing of U of I personnel. The sample was double sealed in large freezer zip lock bags and tested as outlined in section 4.2.

3. DISCUSSION OF TEST RESULTS

3.1 Specific Objectives and Test Matrix

The test was to obtain and document data for determination of particulate and carbon monoxide emission and opacity for compliance after unit modification. Specific test objectives were as follows:

- Measure particulate matter emissions from the boiler stack by EPA Reference Methods 5 (including EPA Reference Methods 1, 2, 3, and 4).
- Measure Carbon Monoxide emissions from the boiler stack by EPA Reference Method 10 using EPA Reference Method 6C QA/QC protocol.
- Opacity was carried out in accordance with Idaho Division of Environmental Quality's "Evaluation of Visible Emissions Manual".

Table 3-1 presents the actual sampling matrix log.

Table 3-1 Sampling Matrix

Date	Run #	Sample Type	Location	Test Method	Start Time	Sample Time
02/26/98	1	CO	Solid Fuels Unit Stack	M10	15:14	62 min
02/26/98	2	CO	Solid Fuels Unit Stack	M10	17:30	63 min
02/26/98	3	CO	Solid Fuels Unit Stack	M10	19:46	99 min
02/27/98	4	PM	Solid Fuels Unit Stack	M5	14:26	scratched due to equipment
02/27/98	5	Opacity	Solid Fuels Unit Stack	IDEQ	14:00	60 min
02/28/98	6	PM	Solid Fuels Unit Stack	M5	08:37	72 min
02/28/98	7	PM	Solid Fuels Unit Stack	M5	12:00	72 min
02/28/98	8	PM	Solid Fuels Unit Stack	M5	15:39	72 min

3.2 Field Changes

No field changes were made.

3.3 Presentation of Results

3.3.1 Particulate Results

Tables 3-2 summarizes the results of the particulate tests. All results are presented in mass/dscf as well as lb/hr. Field data and detailed analysis tabulated by run are found in Appendix C. Cyclonic flow was checked and was not present in the stack per Method One.

3.3.2 Analyzer Tests

Table 3-3 summarizes the results of the carbon monoxide test. All results are presented in mass/dscf as well as lb/hr. Carbon monoxide concentration trends expressed as ppm dry volume are presented in Graphs 3.3-1, 3.3-2, and 3.3-3. Tabulated field data by run for each emission point and a copy of the chart record are found in Appendix B.

3.3.2 Opacity Results

A large attached steam plume existed during opacity determination. Observations were made at the point the steam plume dissipated between 100 and 200 feet down wind of the stack. At this observation point zero opacity was present from smoke. The visible emissions observation form presenting field data for the 60 minute test period is located in Appendix D.

4. SAMPLING AND ANALYTICAL PROCEDURES

4.1 Test Methods

EPA Reference Methods 1, 2, 3, 4, and 5, found in Appendix A of 40 CFR 60 were performed with no deviation. The IDEQ method of Opacity determination was carried out for 60 minutes. EPA Reference Method 10 was performed for determination of carbon monoxide with instrument and system bias checks derived from EPA Reference Method 6C.

Table 3-2 Particulate Emission Results

Parameters	Run #6	Run #7	Run #8	Average
Exhaust Temperature, Ts (F)	280	285	285	283
Exhaust Moisture (%)	21.94	21.67	23.42	22.35
Exhaust Velocity, Vs (fpm)	1787	1807	1944	1846
Exhaust Flow Rate, Qs std (dscfm)	17317	17454	18356	17709
Method 5 Particulate				
gr/dscf	0.0636	0.0575	0.0765	0.0659
gr/dscf @ 8% O2	0.0672	0.0566	0.0880	0.0706
lb/hr*	9.4368	8.6000	12.0354	10.0241

Note: * Particulate emissions reported in lb/hr units were calculated as follows:

$$\text{lb/hr} = (\text{gr/dscf}) \times (\text{lb}/7000 \text{ gr}) \times (\text{dscf}/\text{min}) \times (60 \text{ min}/\text{hr})$$

Table 3-3 Method 10 Summary Table

Concentration data:

Method 10 - CO

Run 1	62 ppm	
Run 2	55 ppm	
Run 3	74 ppm	
Average	64 ppm	4.62E-06 lb CO/dscf*

$$* = (\text{MW}) * 2.59\text{E-}09 \text{ lb/dscf/ppm} * (\text{PPM})$$

Mass Emission Data:

Average Test Conditions:

	Run #1	Run #2	Run #3	Avg.
Stack Temp, F	299	274	282	285
Stack Velocity, ft/s	31.5	29.6	32.0	31.0
Stack Moisture (mass/mass)	0.22	0.20	0.24	0.22
Stack Pressure, "Hg absolute	27.21	27.21	27.21	27.21
Area (ft^2)				18.99

Avg. CO Emission Rate, lb/hr* 6.3

*Based on: (concentration / dscf) * (1-%moisture/100) * Tstd/Tstack *
Pstack/Pstd * stack gas velocity * stack area

$$4.62\text{E-}06 \text{ lb CO/dscf} * (1 - 22/100) * \frac{27.21}{27.21} * 31.0 \text{ ft/s} * \frac{3.2808 \text{ m/s}}{1 \text{ ft/s}} * 18.99 \text{ ft}^2 = 6.3 \text{ lb/hr}$$

4.2 Process Sample Tests

The collected fuel sample was tested for moisture, combustibles, ash, and heating value. Results of this analysis are presented in Table 2-1 and Appendix A.

5. QA/QC ACTIVITIES

5.1 Particulate Testing

No QA/QC problems occurred during total particulate testing.

5.2 Method 5 Train Metering System Audit

The metering system was calibrated against a laboratory based calibration dry gas meter using the procedure specified in Method 5. Appendix C shows the dry gas meter calibration performed in the laboratory prior to this project. Appendix C shows the data from the field calibration check of the instrument. Audit results indicated that the dry gas meter was operating correctly during the test.

5.3 Method 5 Analysis Blank Audits

Field blanks of the acetone used for nozzle and probe rinsing were obtained and analyzed similarly to the acetone wash samples, per the required Method 5 procedures.

5.4 Instrument Analysis

Appendix B presents field calibration checks of the instruments. All results fall within allowable standards.

SOURCE EVALUATION REPORT

**University of Idaho
Moscow, Idaho**



**Wood Waste-Fired Boiler Exhaust
Particulate and Opacity**

January 5, 2005

Project No. 2291

Permit No. T1-040207

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6. DISCUSSION

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Nomenclature & Drift Correction Documentation

Particulate

- Particulate Emissions Results
- Example Calculations
- Field Data
- Blank Corrections
- Laboratory Results, Worksheets, Tare Records, and Chain of Custody
- Sample Recovery Field Data and Worksheets
- Traverse Point Locations

Visible Emissions

- Field Data
- Certifications

Gases

- Molecular Weight Determination
- Analyzer Calibration Data and Bias Checks

Process/Sampling Equipment Flow Diagram

Production/Process Data

- Production / Process Data
- Fuel Characteristics

Calibration Information

- Meter Box and Standard (Critical Orifices)
- Pitots
- Thermocouples and Indicators
- Nozzle Diameters
- Barometer
- Calibration Gas Certificates

QA/QC Documentation

- Procedures
- Analyzer Interference Response Data

Correspondence

- Source Test Plan and Correspondence
- Permit (Selected Pages)

1. CERTIFICATIONS

1.1 Test Team Leader

I hereby certify that the test detailed in this report, to the best of my knowledge, was accomplished in conformance with applicable rules and good practices. The results submitted herein are accurate and true to the best of my knowledge.

Name: Thomas A. Rhodes, E.I.T.

Signature _____ Date _____

1.2 Report Review

I hereby certify that I have reviewed this report and find it to be true and accurate, and in conformance with applicable rules and good practices, to the best of my knowledge.

Name: David R. Rossman, P.E.

Signature _____ Date _____

Expires 12/31/2006

1.3 Report Review

I hereby certify that I have reviewed this report and find it to be true and accurate, and in conformance with applicable rules and good practices, to the best of my knowledge.

Name: Michael E. Wallace, P.E.

Signature _____ Date _____

2. INTRODUCTION

2.1 Client: University of Idaho
Facilities Management

2.2 Physical Location: Power Plant
Moscow, Idaho

2.3 Mailing Address: 1108 W. Sixth Street
Moscow, ID 83844-2030

2.4 Test Log:

Wood-Fired Boiler Exhaust: Particulate and Opacity

Test Date	Run No.	Test Time
January 5, 2005	1	08:38 – 09:40
"	2	10:09 – 11:12
"	3	11:34 – 12:36

Summary: Three valid runs

2.5 Test Purpose: Compliance with Operating Permit No. T1-040207
issued by the Idaho Department of Environmental Quality (DEQ).

2.6 Background Information: None

2.7 Participants:

Horizon Personnel:

Thomas A. Rhodes, E.I.T., Team Leader
Michael E. Wallace, P.E., Calculations and QA/QC
David R. Rossman, P.E., Report Review
Kate Krisor, Technical Writer

Test Arranged by: Mike Lyngholm, University of Idaho

Visible Emissions (Opacity) Read By: Mike Lyngholm

Observers:

Plant Personnel: Mike Lyngholm

Test Plan Sent to: Clayton Steele, Idaho DEQ

3. SUMMARY OF RESULTS – 3.1 Table(s) of Results:

Table 1

Wood-Fired Boiler Test Results

Test Date: January 5, 2005	Units	Run 1	Run 2	Run 3	Average
Start Time		08:38	10:09	11:34	
End Time		09:40	11:12	12:36	
Sampling Time	min	60	60	60	60
Sampling Results					
Particulate-Filterable (Actual)	gr/dscf	0.039	0.038	0.031	0.036
Conc. @ 8 % O ₂	gr/dscf	0.038	0.036	0.028	0.034
Permit Limit 8% O ₂	gr/dscf				0.08
Particulate Rate	lb/hr	6.7	6.4	4.5	5.9
Permit limit	lb/hr				17.24
Opacity	%	1	1.5	1	1
Sample Volume	dscf	47.8	46.5	42.2	45.5
Sample Weight, Filterable	mg	120	115	84	106
Percent Isokinetic	%	96	97	97	97
O ₂	%	7.8	7.1	7.0	7.3
CO ₂	%	12.2	12.9	13.0	12.7
Source Parameters					
Flow Rate (Actual)	acf/min	37,900	37,600	32,000	35,800
Flow Rate (Standard)	dscf/min	20,200	19,600	17,300	19,000
Temperature	°F	315	322	304	314
Moisture	%	16.0	16.7	15.8	16.2
Process/Production Data					
Steam Production	10 ³ lb/hr	56.5	57.3	53.2	55.7
Total Wood Burned During Test	BDT				24
Multiclone Pressure Drop	in. H ₂ O	2.6	2.6	2.2	2.5

3.2 Description of Collected Samples:

Filters: Grey

Impinger Contents: Clear

3.3 Discussion of Errors and Quality Assurance Procedures: This table is taken from a paper entitled "Significance of Errors in Stack Sampling Measurements", by R.T. Shigahara, W.F. Todd and W.S. Smith. It summarizes the maximum error expressed in percent, which may be introduced into the test procedures by equipment or instrument limitations.

Measurement	% Max Error
Stack Temperature T_s	1.4
Meter Temperature T_m	1.0
Stack Gauge Pressure P_s	0.42
Meter Gauge Pressure P_m	0.42
Atmospheric Pressure P_{atm}	0.21
Dry Molecular Weight M_d	0.42
Moisture Content B_{ws} (Absolute)	1.1
Differential Pressure Head ΔP	10.0
Orifice Pressure Differential ΔH	5.0
Pitot Tube Coefficient C_p	2.4
Orifice Meter Coefficient K_m	1.5
Diameter of Probe Nozzle D_n	0.80

3.3.1 Manual Methods: QA procedures outlined in the test methods were followed, including equipment specifications and operation, calibrations, sample recovery and handling, calculations and performance tolerances.

On-site quality control procedures include pre- and post-test leak checks on trains and pitot systems. If pre-test checks indicate problems, the system is fixed and rechecked before starting testing. If post-test leak checks are not acceptable, the test run is voided and the run is repeated. The results of the quantifiable QA checks for the test runs are on the Field Data sheets.

Horizon does semi-annual calibrations on pitots, thermocouples, and nozzles. Pitots are examined before and after each use to confirm that they are still aligned. Pitot systems are leak-checked before traverses begin, and after runs are completed (before any component disassembly). The results were within allowable tolerances. Prior to use, thermocouple systems are checked for ambient temperature before heaters are started or readings are taken. Problems with connections or polarity are obvious from these and readings as temperatures rise.

3.3.2 Continuous Analyzer Gas Sampling: Analyzer system checks performed are noted on the Calibration Field Record sheet, with procedures documented in the QA/QC section in the Appendix. All calibration standards used in the testing were EPA Protocol 1. Certificates for the gases are in the Appendix.

4. SOURCE DESCRIPTION AND OPERATION

4.1 Process and Control Device Description and Operation:

The wood fired boiler was manufactured by Nebraska, Model S-B00 and is rated at 60,000 pounds of steam per hour. The boiler is used to produce steam for heating the campus during cold weather and to provide steam to absorption chillers to cool the campus buildings in summer. During the testing the boiler steam production averaged 55,700 pounds per hour.

A multiclone controls particulate emissions.

Average Boiler Fuel Sample Information

Wood used during the test was brought to the site in two separate trucks.

One representative sample per truckload was collected.

Primary Fuel: Hogged Fuel

Wood (estimated): White: 80%

 Bark: 20%

Average Moisture, % Wet Basis: 37%

Average Percent Dry Fuel <1/8": 7%

4.2 Test Ports: Ports and traverse points are described and diagrammed on the Field Data sheets.

4.2.1 Test Duct Characteristics:

Construction: Steel

Shape: Circular

Size: 58.75 inches inside diameter

Orientation: Vertical

Flow straighteners: None

Extension: None

Cyclonic Flow: None expected

Meets EPA M-1 Criteria: Yes

4.3 Process & Control Equipment Flow Diagram: See
Process/Sampling Equipment Flow Diagram in Appendix

4.4 Operating Parameters: See Production/Process Data section of
Appendix

**4.5 Process Startups/Shutdowns or Other Operational Changes
During Tests:** Process was continuous during testing.

5. SAMPLING AND ANALYTICAL PROCEDURES

5.1 Sampling Procedures:

5.1.1 Sampling and Analytical Methods: Testing was conducted in accordance with EPA Methods in Title 40 Code of Federal Regulations Part 60 (40 CFR 60), Appendix A, July 1, 2002.

Flow Rate: EPA Methods 1 and 2 (S-type pitot w/particulate traverses)

CO₂ and O₂: EPA Method 3A (integrated Tedlar bag sample, NDIR and paramagnetic analyzers)

Moisture: EPA Method 4 (incorporated w/ M-5)

Particulate: EPA Method 5 (filterable material only)

Opacity: EPA Method 9 (thirteen minutes per test)

5.1.2 Sampling Notes: To obtain the fuel moisture content, the wood fuel samples were placed in an oven set at approximately 220°F. The samples are normally dried for 24 hours, however the samples were left in the oven for four days. The entire wood sample obtained during the testing was dried, so it was not possible to repeat the test. The average moisture was 37%, very similar to the plant's measurement of moisture (average 39%) for both truckloads. These results are for information about the fuel used in the boiler, and are not used in any other calculation.

5.1.3 Laboratory Analysis:

Analyte	Laboratory
Particulate	Antech

5.2 Sampling Train Diagrams:

Figure 1
EPA Methods 1, 2, 4, & 5 Particulate Sample Train Diagram

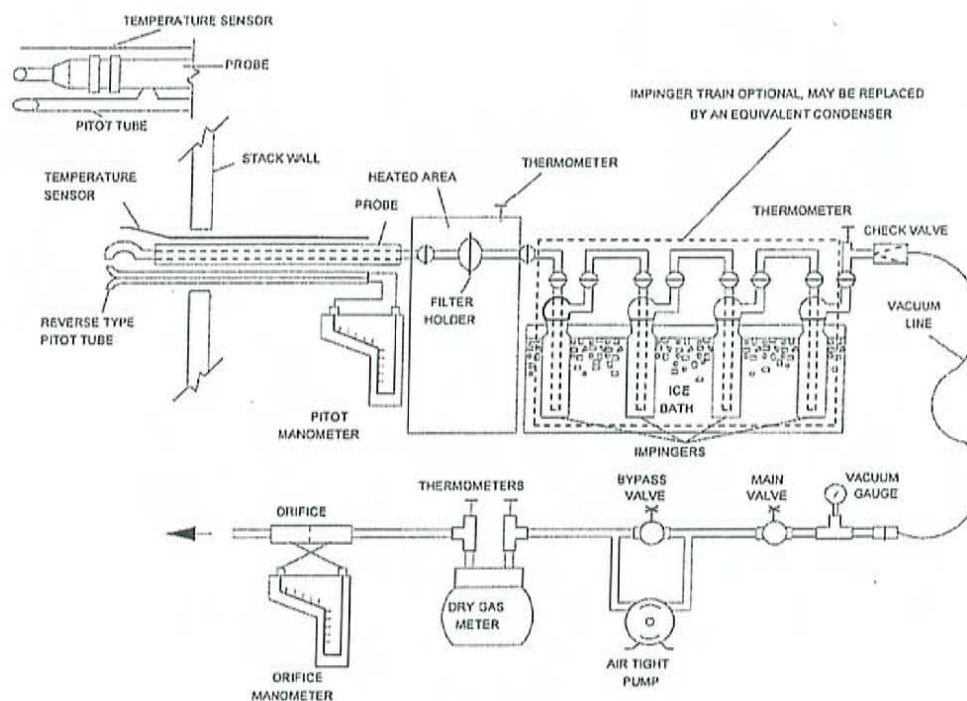


Figure 5-1. Particulate Sampling Train

5.3 Horizon Test Equipment:

5.3.1 Manual Methods:

Equipment Name

Identification

Meter Box

Graseby Model 2010A, Horizon No. 7

Inclined Liquid Manometer

Incorporated with H.E. No. 7

Probe Liner

Stainless Steel

Pitots and Thermocouples

5-2, 5-5, 5-6

Stainless Steel Nozzles

607, 611, 621

Barometer

Test Van III

5.3.2 Continuous Emissions Monitors and Methods:

Gas	Brand	Model	Range	Measurement Method	Method
O ₂	Servomex	1400	0-25%	Paramagnetic	3A
CO ₂	Servomex	1400	0-25%	Chopperless NDIR	3A

5.3.3 Tedlar Bag Sampling Setup:

Probe: Stainless Steel
Pump: Squeeze bulb

6. DISCUSSION

The results of the testing should be valid in all respects. All quality assurance checks including leak checks, instrument checks, and calibrations, were within method-allowable tolerances.